Review Article

Dental Age Estimation using the Cameriere Method in Different Countries: A Review

Desprika Youhana Sitio*, Ghora March Eka Solehuddin and Grace Sisilia Panjaitan

Master of Forensic Science, Airlangga University, Airlangga St, Surabaya, 60286, Indonesia

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Abstract

Age estimation is an essential aspect of profile building in forensic investigations. Age estimation using teeth is one of the exciting applications of Forensic Odontology because teeth can survive post-mortem damage, so it is considered more suitable for age estimation. This study aims to estimate the age of individuals using the Cameriere method on teeth in various countries. The approach used in this research is a literature review study design compiled based on the Preferred Reporting System for Systematic Reviews and Meta-Analyses (PRISMA) guidelines from several articles with a period from 2007-2024. Scientific articles that meet the criteria will be analyzed using the Cameriere method to estimate the age of individuals. The search yielded 222 studies and only 12 scientific articles that met the requirements from the specified articles obtained. The population represents countries from various countries. The sample was in the age range of 4 years - 16 years. The results showed that the Cameriere method can be used to estimate the age of individuals quite accurately in various countries. However, there were some differences in accuracy between countries when using this method.

Introduction

Forensic science is a comprehensive science that aims to support the forensic identification process. Anthropology is one of the scientific fields in forensic science. Part of forensic identification in forensic anthropology is individualization, age, gender, size, and race. Age estimation is an important aspect of the identification process. Age is a biological characteristic that can be estimated using biological and chronological age estimation techniques [1]. Chronological age is determined based on the day, month, and year of birth. In general, somatic development is related to chronological age in somatic measures of maturity, such as bone age, maturity, and height. Biological age can be estimated by looking at the skeleton and teeth parameters. Dental age is determined based on the stage of tooth eruption and tooth formation or maturation [2].

In general, teeth and supporting bones are used for age estimation. They are used from the prenatal stage to adulthood. Moreover, teeth are a part of the human body that has advantages due to their nature: it is hard even after being burnt to a temperature of ± 900 °C, they are not easily damaged during storage, they are firmly attached to the jawbone, it is resistant to pressure and chemical effects, and it is not subject to decay. Biological events, such as tooth eruption and the stage of tooth development, are usually used to estimate age. The age estimation method by dental examination on this occasion uses the panoramic radiography method by looking at radiographic images of individual teeth. This method can be applied to living and dead individuals [3,4] and is a simple, non-invasive method.

Estimating a person's age can be based on dental maturation using the eruption stage and dental calcification. The method that uses the stage of tooth eruption time has shortcomings, including the difficulty of determining the actual eruption time because the event occurs quickly. The clinical assessment is influenced by local factors, systemic diseases, and diet [5]. In 2006, Cameriere conducted a new method of research. This method was tested by Cameriere and other researchers with different samples, resulting in a good age estimation that was more accurate than the method proposed by Demirjian. The Cameriere method is an age estimation method that uses the apical part of the tooth by measurement of open apices for age estimation [6]. This method uses a formula for age estimation in children using dental radiographs. This formula uses specific normalized tooth measurements (measured on a computer

screen using image processing software) and a regression formula to calculate age [7]. The coefficient of determination shows that the variable of the Cameriere method can explain 80.7% of the variation in chronological age. Other factors determine the remaining 19.3%. The standard error of the estimate has a small value of 0.756, which means that this regression model is a good predictor of age [8].

Studies on children in Iran and Telangana using the Cameriere method have shown that age estimation results are quite accurate [9,10]. However, another study of children in northern Germany found a difference between the calculated age and the chronological age (below or above the estimate) [11]. Currently, the Cameriere method is not widely used in Indonesia. The children in Indonesia, especially in Bandung, have been the subject of a research study on the Cameriere method. Based on the study's results, it can be concluded that the Cameriere method can be used to estimate the chronological age of children [8] accurately. Similar research, which showed that the Cameriere method can be used as an age estimation method, was also conducted at the Radiodiagnostic Laboratory of the Faculty of Dentistry, Universitas Brawijaya (FKG UB) [6].

Methods

This research method was conducted with a Systematic Literature Review (SLR) approach based on PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) where the research questions were organized based on Population (P), Intervention (I), and Outcome (O) as follows: "Is the determination of age estimates from the child to adolescent age population (P) using the Camieriere method (I) accurate?" (O). The inclusion criteria in this study are English journals, articles from various countries, full text, data used in the 2006-2024 time range, and formulas. The exclusion criteria were systematic review and meta-analysis studies. Data sources were obtained from the Science Direct, Scopus, and Google Scholar databases with Publish or Perish (PoP) software. Search keywords using the auxiliary word "OR" Then search for journals by entering keywords: Application* OR implementation*usage* of Cameriere Method* OR mechanism* for Age estimation" (Table 1).

Study selection

1. Identification: The identification of the literature is the result of the literature search in the database. The results are then stored in the Zetero data processing application on the desktop. After that, the data identified as duplicates by the system are deleted. In addition, literature in the form of books has also been deleted.

2. Screening: Screening is performed to remove literature that does not meet inclusion criteria. Literature that does not discuss estimating age using the Cameriere Method and does not include formulas will be deleted.

3. Included: The selected literature is a study that discusses age estimation using the Cameriere method includes formulas and uses English.

Results

The results of the literature selection analysis resulted in 222 studies from three databases. From the results of the analysis found as many as 22 scientific articles that are the same then removed and the remaining 200. Then it was found that 144 articles did not meet the criteria then removed and the remaining 56 entered the screening stage. After that, of the 56 articles, 15 did not meet the criteria for the population, 13 articles did not include the formula and 17 articles did not use the Cameriere method and were deleted. Then the final result was 12 articles to be analyzed. The article selection process can be illustrated using a flowchart (Figure 1).

Discussion

This study compares the formula results of the Cameriere method applied to different populations. The comparison is organized in Table 2. It consists of the author and year of publication, article title, sample size, age, population, and formula. From the formula, it can be analyzed whether the Cameriere method is effective in this population.

Table 1: Keywords in the database search.

Database	Keywords	Result
Google Scholar https://scholar.google.com/		100
Science Direct https://www.sciencedirect.com/	Application* OR implementation*usage* of Cameriere Method* OR mechanism* for Age estimation".	100
Scopus https://www.scopus.com/		22

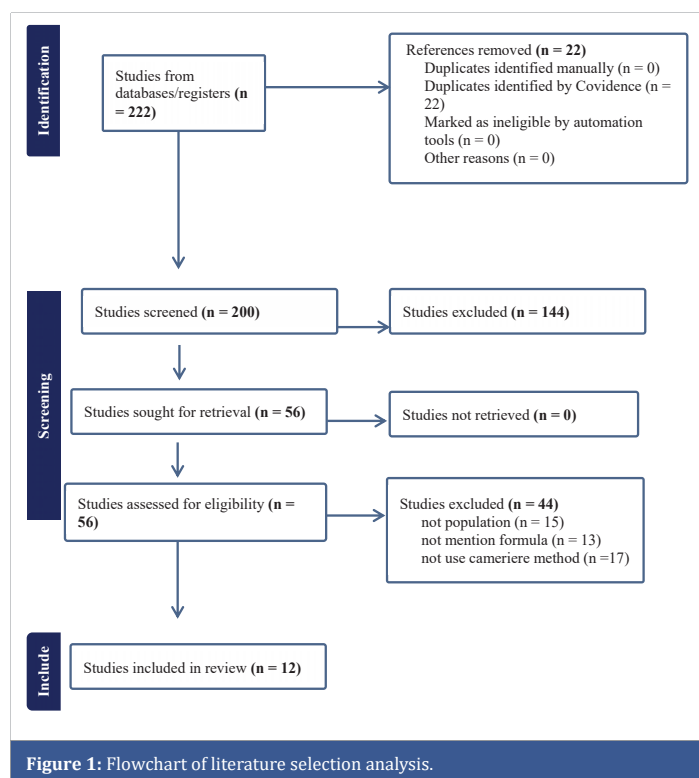**Figure 1:** Flowchart of literature selection analysis.

Table 2: Literature review on age estimation based on teeth using the Cameriere method in various populations.

Author (Year)	Title	Population	Sample total	Age	Formula
Cugati, Navaneetha, et al. 2015[12]	Dental age estimation of growing children by measurement of open apices: A Malaysian formula	Malasya	421 M = 176 F = 245	5-16	Age = 11.368 - 0.345 $_g$ + 0.553 $_{No}$ - 1.096 $_s$ - 0.380 s.N
Valluri, Ratna, et al. 2020[13]	Age Estimation in Mixed-dentition Children, Using Cameriere's European Formula and Demirjian's Method: A Comparative Pilot Study	Telangana	36 M = 15 F = 21	7-12	Age = 8,971+ 0,375 $_g$ + 1,631× 5 + 0,674 $_{N0}$ -1,034s - 0,176s- $_{N0}$
Begum, Chandhini, et al. 2017[14]	Dental age estimation by using cameriere's method in Mangalorean children: a pilot study	India	40 M = 17 F = 23	7-16	Age = 13,868 - 6,400 (x4) - 2,054
Sam, Belly, et al. 2021[8]	Application of Cameriere Method for Age Determination in the Deutero-Malay Population	Subras Deutro Melayu	240 M = 120 F =120	6-12	Age = 10,845 + 0,140 $_g$ + 1,421 $_{x5}$ + 0,297 $_{N0}$ - 1.284.s - 0,10.s*N0
Halilah, Talal, et al. 2018[15]	Age estimation in 5- 16-year-old children by measurement of open apices: North German formula	Jerman Utara	1000 M = 444 F =556	5-16	Age = 9,829 + 0,632 N0 - 1,037s + 0,686g - 1,582N0 × X3
Kis, Hatice, et al. 2020[16]	Evaluation of Willems and Cameriere's dental age estimation methods in Turkish children–A modified version of Cameriere's method	Turki	1878 M = 972 F = 906	5-15	Age = 8,387 + 0,282*g + 1,692*X$_5$ + 0,835*N$_0$ - 0,116*$_s$ - 0,139*$_s$*N$_0$
Fernandes, Mario et al,. 2011 [17]	Age Estimation by Measurements of Developing Teeth: Accuracy of Cameriere's Method on a Brazilian Sample	Brazil	160 M = 66 F = 94	5-15	Age = 8,971 + 0,375 $_g$ + 1,631 $_{x5}$ + 0,674. *N* - 1,034.*S* - 0,176.*S.N*
Ozveren, Neslihan, et al. 2019 [18]	comparison of the accuracy of Willems' and Cameriere's methods based on panoramic radiography	Turki	636 M = 319 F = 317	6-15	Age = 8,971 + 0,375.g + 1,631.X$_5$ + 0,674.N - 1,034.S - 0,176.S.N
Kalinowskaa, Ingrid, et al. 2020 [19]	The Cameriere method using cone-beam computed tomography (CBCT) scans for dental age estimation in children	Krakow Polandia	212 M = 60 F = 61	5-13	Age = 8,971 + 0,375g + 1,631 x$_5$ + 0,674N$_0$ - 1,034s- 0,176sN$_0$
Cameriere, Roberto, et al. 2007 [20]	Age estimation in children by measurement of open apices in teeth: a European formula	Kaukasia Eropa	2.652 M =1.382 F = 1.270	4-16	Age = 8,387 + 0,282 $_g$ - 1,692 × 5 + 0,835 N$_0$ - 0.116 s - 0.139 $_s$ - N$_0$
Bagh, Tapaswini, et al. 2014 [21]	Age Estimation Using Cameriere's Seven Teeth Method with Indian-Specific Formula in South Indian Children	Mangalore	25 M = 14 F =11	5-15	Age = 9,402 - 0,879c + 0,663 $_{No-0}$,711s-0,106sNo
Yang, Zedeng, et al. 2022 [22]	Application of Cameriere's method for dental age estimation in children in South China	Cina Selatan	803 M = 400 F = 403	4-15	Age = 0,575 + 0,343g - 2,605x$_3$ -2,343x$_4$ + 0,594N0 -0,416s-0,170s - N$_0$

Notes:
g = variable boys (1) and girls (0).
C = boy (1) and girl (0) variables.
S = sum of A/L ratios for each tooth at the open apex.
s.N0 = Interaction between s and N0 variables.
N0 = number of teeth with complete root development or teeth with completely closed root apical tips.

The age estimation is an important profile in the construction of forensic investigations. An interesting application of forensic odontology is age estimation using teeth. Teeth are the strongest component of the body and can withstand physical and chemical hazards, extreme temperatures, and even nutritional deficiencies [23,24]. In forensic science, several different techniques have been used to determine a person's age and have produced mixed results. However, most of these techniques are limited to use with deceased individuals. Estimating a person's age can be done in several ways using different characteristics, such as age by following the growth of the dentition because teeth are the most robust biological material to environmental changes. A person's age can be estimated and determined by looking at the teeth from a morphological, histological, and radiological point of view [25].

They contain inorganic hydroxyapatite crystals, which coat the tooth tissue and provide a high degree of resistance to changes in temperature, various external stimuli, mechanical irritants, and chemicals [26]. Tooth-based age estimation procedures identify many things, including eruption, tooth morphology, and stages of tooth calcification, which can be identified using radiographic techniques. Complicated radiographic developments like the initial mineralization, crown formation, and root growth are readily apparent [27]. A radiographic technique is a technique that is easy to perform on a person who is either alive or dead. The most commonly used radiographic techniques are intraoral periapical, cephalometric, lateral oblique, and panoramic radiographs [28].

Panoramic radiography is considered the best tool for age estimation in children. Panoramic radiography is an ideal screening tool because of its low cost, ease of use, and ability to view the entire dental arch without obstruction. Based on this, it is concluded that this technique can provide reliable and reproducible intra- and interobserver measurements [13]. For the application of the Cameriere technique, the public domain image processing program ImageJ was used to obtain the measurements. The first seven permanent mandibular teeth from the left side were considered. The number of teeth with

complete root development, with closed apices, was recorded as the "N0" value. The next parameter recorded was "Ai" - the distance (for single-rooted teeth) or the sum of distances (for double-rooted teeth) between the inner side of the open apex (i = 1, 2, 3, 4, 5) or apex (i = 6, 7). These values are then divided by the corresponding tooth length ("Li", where i = 1,...,7) to normalize the effects of possible differences in magnification and angulation observed on the radiograph. Therefore, the seven mandibular first molars' normalized measurements (xi) were obtained from the formula $xi = Ai/Li$, where $i = 1,...,7$ [29]. The measurements on the teeth can be seen in Figure 2. Li is the measurement from the highest cusp/incisal tip to the apex and Ai is the lateral width at the open apex.

The height and width of the open apex teeth were measured with the help of Fiji ImageJ. It is an open-source software released in 2012 for the analysis of biological images, the calculation of areas and pixels, the measurement of distances and angles, the manipulation of contrast, the detection of edges, and the filtering of the median. Fiji ImageJ can be used as a valid and reliable measurement tool. Fiji ImageJ is one of the most recent open-source software, and it has been widely used in several studies. Based on the results obtained, this study has several strengths, such as using multiple linear regression to improve accuracy and using Fiji ImageJ as an open software that can be easily obtained, easy to use, and practical. Certain limitations must also be considered for future investigations. It is recommended that future studies pay attention to the quality of radiographs, specimens, and visual errors, as these cannot be controlled. This method can be used for men and women, as no significant difference exists between gender groups [8].

The results were accurate based on the results of a study conducted by Latić-Dautović, et al. on a population of children in Bosnia and Herzegovina using the Cameriere method. Likewise, Cugati, et al. developed the Cameriere formula using linear regression on a Malaysian sample. Their results showed that the constant and variable coefficients of the Cameriere method could be affected by varying environments, diet, growth rate, and ethnicity [13,30]. The European formula of Cameriere, et al. was chosen because a double check of the

Figure 2: Li and Ai measurement method in the Cameriere method [13].

OPG showed no statistically significant differences between observers, although it requires more calculation steps. The European formula technique of Cameriere, et al. was found to be faster and easier to use than other quantitative techniques [31].

Cameriere's dental development varies from individual to individual and shows regional and ethnic differences, therefore it may not be appropriate for use in other countries. Diet, lifestyle, dietary habits, and socioeconomic level influence dental development. For this reason, some authors propose the Cameriere approach as the most accurate method for the population of this decade, adapting the Cameriere regression model to more recent samples to fit their population [7]. Note that the previously proposed dental age estimation techniques do not result in a formula that can be universally applied to the world population [27]. This study only used the age range of 6 to 12; therefore, further research with other methods, such as Willems or Demirjian methods, for different ages is needed [8].

Conclusion

The Cameriere method is an easy-to-use, inexpensive, and accurate method for estimating the age of children and adolescents. It can be useful in forensic identification. The use of the Cameriere method may vary from country to country. Some countries may have their own standards and guidelines for this method. This method estimates the age of children by measuring the open tips of the teeth using a linear regression formula.

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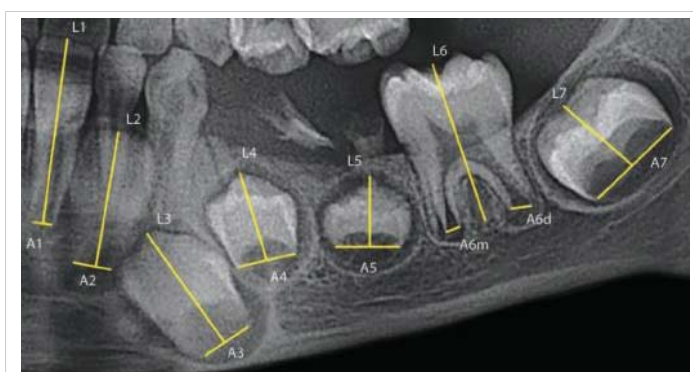
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